Fault Tolerant Routing In Heterogeneous Environment

Madhumita Panda, Pinakini Pradhan, Hitesh Mohapatra, N.K.Barpanda

Abstract: The information exchange is one of the important aspects of a modern and improved life. Nowadays every component such as home appliances, vehicle, and grocery everything is equipped with sensors or RFID, which are communicating with each other over Wi-Fi technology. The occupancy of the internet in day-to-day objects introduces the concept called the internet of things (IoT). The function of IoT is integral of wireless sensor network and sensors. The dense deployment of sensors in different objects and their intention to communicate over the internet creates a challenge of routing. Clustering is one of the proven methodologies for routing mechanism. The major constraints of existing protocols are consideration of less of sensor nodes, which is not true in real sense. Hence, the development of an algorithm by considering a dense amount of SN is a very critical challenge. In this paper, we have studied the existing routing schemes and proposed a new algorithm called Heterogeneous Fault- Tolerant Routing (HFTR) protocol, which ensures prolonglifetime of sensor network with better dead node ratio against the number of the electoral rounds.

Keywords: Wireless sensor network, routing, IoT, clustering, energy efficiency, heterogeneous, fault tolerant.

1. INTRODUCTION

Internet of Technology(IoT) is a network of similar or different types of objects. Here, the objects are usually occupied with sensors or radio frequency identification (RFID) tags. These sensor-based objects extend the use of the internet by exchanging information among them. IoT brings all such objects under a common network to enable inter-communication. The various short-range communication technologies are RFID, Bluetooth, ZigBee, etc. For instance, the clothes with RFID tag when used for washing in the washing machine then the washing machine can learn from RFID tags and able to adjust water requirement. Another example is Bluetooth, for short-range communication between compatible devices. In this way, the different types of objects can be configured for inter-communication [1]. Figure 1 illustrates the involvement of IoT in various smart applications. The IoT facilitates a wide range of applications to behave in a smart way, such as smart home appliances like an air conditioner, washing machine, television, air, and water pollution control, traffic management, etc. There are several projects, which are working to bring the distributed networks under common IoT-based network (Ex. SENSEI Project) [2]. During such a heterogeneous environment, routing with energy efficiency is a critical challenge. In spite of extensive research routing in a dense environment demands significant attention by considering sensor node (SN) localization and distance from BS[3].

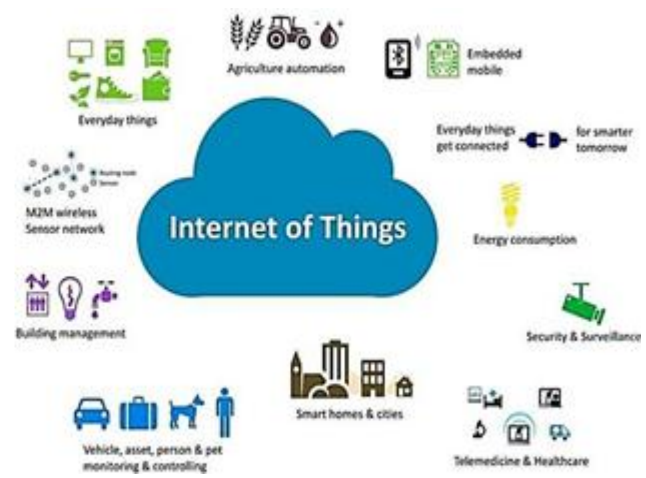

Fig.1. *IoT Applications*

Source: *{https://www.xtendiot.com/top-internet-things-application-areas/?subject}*

The existing simulation environment primary assumes the static or dynamic deployment of SN and forwarding of data to the base station (BS) through multi-hop fashion. This multi-hop communication sometimes overburdens the SNs, which leads to rapid energy depletion. Another, major problem during the routing process is the irregular size of packets, which creates uncertain delay at sending and receiving points. Thus, in this paper, we have proposed a movable BS based energy efficient routing protocol named Heterogeneous Fault-Tolerant Routing (HFTR) protocol. The rest of the paper has been organized as follows: section 2 covers the literature review, section 3 gives the proposed model and algorithm used in the paper,section 4 gives the simulation results and analysis while section 5 has a conclusion followed by references.

- *Madhumita Panda1, Pinakini Pradhan2, Hitesh Mohapatra3,N.K.Barpanda4*
- *1,2,4 Sambalpur University, Odisha, India*
- *3 Veer SurendraSai University of Technology, Burla, Odisha, India*
- *Corresponding author. Madhumita Panda. Email: mpanda.suiit@gmail.com*

2. LITERATURE REVIEW

The beginning of routing starts with low energy adaptive clustering hierarchy (LEACH) [4] protocol. In this protocol, a node is selected as a cluster head (CH) by considering its residual energy (Re) level. LEACH applies a random probabilistic method by which the current Re of any random SN is compared against the prefixed threshold Re. If it is more or equal then for that round that randomly selected node becomes CH. This process iterates in every new electoral round. The main objective of LEACH is to reduce system delay and energy consumption. In [5], the authors have been proposed Threshold sensitive Energy Efficient sensor Network (TEEN) protocol, which primarily focuses on trade-off between energy efficiency, response time and accuracy. It is reactive routing protocol, which creates a route on reaction basis that means when the node senses an event and trying to forward the collected data from the event to a specified destination then only the path is established between source and destination. Another approach towards routing is proactive routing where the path already exists among all SNs. So, each SN has a big routing table for path information [6]. The proactive routing is not suitable for densely deployed sensor network because each node needs to store a huge table of routing information, which violates the memory constraint architecture of WSN [7]. There are few protocols such as SPIN, Flooding, etc., which have been proposed by considering flat routing process. In flat routing, the sensor node communicates with BS through multi-hop communication process, but the major drawback of this routing method is the nodes, which are closer to the BS getting dried with energy quickly because of unnecessary participation in unintended communication [8]. Hence, to overcome the problems with direct routing and flat routings such as collision, delay, overhead and more energy consumption a new cluster-based routing method came into execution [9]. In cluster-based routing, the formed clusters communicate with each other through CH. The CH collects the data from all of its cluster members and communicates that data with the BS [10]. As few CHs are participating in the communication process instead of all SNs, it helps to reduce congestion in traffic and energy consumption at the node level, etc. There are again several algorithms exist to select efficient CH in WSN. In a few cases, the combined routing process is effective which also called as Hybrid routing protocols. Fig.2 illustrates our study in a taxonomicalform.

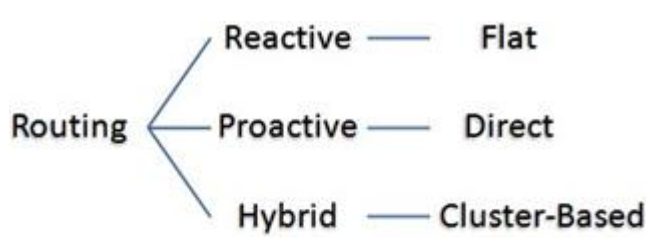

Fig.2 *Routing Taxonomy*

Later on the state in a few protocols, the BS played an active role of CH selection. The algorithmDynamic State Clustering (DSC) adopts the BS based CH selection process to overcome the problem of CH selection in every round. Here, instead of each round the CH selection process iterates in every 10th round [11]. However, due to a large amount of data transaction, DSC also not an energy efficient model. However, these all above-said algorithms provide routing mechanism but these fail to provide an efficient fault-tolerant mechanism. In [12] the authors proposed Periodic, Event Driven and Query-Based Routing (PEQ) Protocol, which ensures fault recovery, accuracy, and energy management. PEQ adopts hop-tree paradigm where each level decided by the hop count value. In [13] Mohapatra H et al. demonstrated the EnergyBalanced Cluster formation (EBCF) technique where the focus has paid on equal load distribution among clusters, which promises to prolong the network lifetime by reducing the burden of unequal load distribution. Our study says that routing in static network is somehow, manageable, but in mobile-WSN (MWSN) routing is the major critical challenge, as the node does not have any specific location. In the above said context, Energy efficient and Fault Tolerant Clustering Protocol (EFTCP) introduced a new theme of proving alternative nodes for CH. In EFTCP, CH assigns a particular time slot for SN to transmit their data. Clustering- based Multi-Path Data Dissemination scheme (CMPDD) is another approach towards cluster-based routing scheme [14-16]. Fig.3 illustrates the traditional architecture of cluster-based routing.

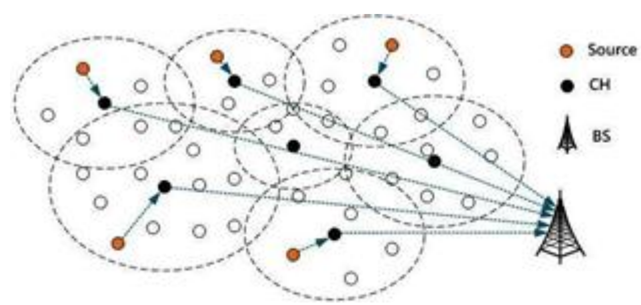

Fig.3 *Cluster-Based Routing in WSN*

3. PROPOSED MODEL

In this section, we have proposed and discussed the Heterogeneous Fault-Tolerant Routing (HFTR) protocol. The HFTR primarily based onheterogeneous types of node networking. These nodes have different computational power and a different set of data. Routing in a heterogeneous environment invites many challenges such as delay, compatibility issue, transmission time, etc. Here, we have considered a set of constraints to execute HFTR. The performance of HFTR has measured in terms of sensor network lifetime and node dead ratio.

3.1 Network Model

We have made few assumptions to design the HFTR protocol. The constraints are as follows:

1. The sensor network is static in nature.
2. The sink node or base station (BS) is mobile in nature.
3. Alltheheterogeneousnodeshaveallinformationlikelocationandresidualenergylevel.
4. BS rotates as per TDMA schedule.
5. BS is full of resources such as memory and computational power.
6. Cluster head (CH) has authority to generate priority value and that will be broadcast to rest CH.

3.2 Working Model

In our proposed scheme the total sensor network divided into few clusters and each cluster have been monitored by dominating node called CH. The CH is responsible for collecting data from all SNs and waits for its turn to send that aggregated data to the BS. The uniqueness of our proposed model is we have assumed a mobile BS, which rotates in a circular path through all formed clusters. When the Euclidean distance between BS and CH found minimum it provides a stipulated period to that particular CH to transmit its part of collected data. After, data collection the BS moves to next cluster and continue the same process. The iteration will continue until all clusters get covered by the mobile-BS. In meanwhile after collection of data from one CH the BS immediate forward that to the server over the internet. This will help to ménage the memory at the BS level. The second benefit is as BS movers close the CH hence CH utilizes less of its energy to transmit the data. Fig.4 illustrates the working model of HFTR protocol.

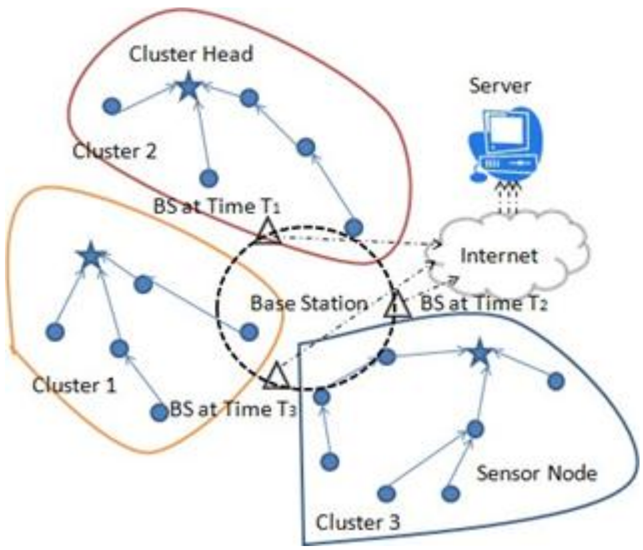

Fig.4 *Working Model of HFTR Protocol*

3.3 Proposed Algorithm

Initially dozen of SNs and one BS are deployed in the heterogeneous sensor network. The sensor node where, SN ϵ N and N= {1, 2, 3, …, n}. The BS rotates though all clusters with time T where T = {1, 2, 3...tn}. In meanwhile, the elected CH collects data from its corresponding cluster members to aggregate and keep ready to forward that data to the BS as per the TDMA schedule assigned by the BS for all CHs. The total data collected by each CH is given in Eq.1.

$$Total\ Data(CH) = \sum_{SN=0}^{n} SN \quad \textbf{(1)}$$

The BS provides a set of priority value (P) to all the CH. The priority set depends upon the number of clusters formed. In our case, we have formed three clusters hence, the priority value P may set to any of these three-prefixed values that are P = {1, 2, 3}. Again, the CH cannot choose any random priority value rather the priority value will be set to 1 if the total occupied memory of CH is closer the total memory of CH and so on 2 and 3. This can be represented as:

$$Assign\ (P=1) \quad \textbf{(2)} \quad 2$$

If (occupied memory (CH) ≈ Total memory (CH))

Once the priority value gets chosen by one CH that will be broadcasted among all CH so that rest CH will go for other priority value form their main P. That helps to reduce ambiguity among CHs.

HFTR Algorithm:

1 Input
SN, BS, TDMA Schedule
2 Initialize
SN Deployment
SN = {SN1, SN2, SN3…SNn}
Cluster Formation C = {C1, C2, C3}
CH Selection
CH = {CH1, CH2, CH3}
3 Process
Initiate Rotation of BS Rotate (BS);
Generate(P) by CH
Initiate TDMA Schedule for CHs Wait BS Until Timeout
Transmit;
CH (data)→BS (Within Time Frame) Timeout;
BS moves to next CH
4 Repeat: Step 3
Until all CH transmit there data.
5 Repeatforeveryneweventsensing
6 Stop

4. RESULTS AND ANALYSIS

In this section, we present simulation and result from analysis. For simulation purpose, we have considered the following input parameters as presented in Table 1. In this simulation, we have considered the 100 × 100 area as our simulation model. The SNs are non-uniformly distributed over the clusters. Every execution round comprises of two phases, one is set-up phase and the second one is the steady-state phase. The outcome of our simulation measured with two validation parameters, the first one is the sustainability of network against the number of electoral rounds and the second one is node death ratio. The performance of HFTR has been compared against the two well-known existing algorithms that are LEACH and TEEN.

Parameters	Value
Network area	100 m X 100 m
Number ofsensors	Max 100
Energy consumptions for sending data packets	50 n Joule/bit
Initial node energy	2000 Joules
Number of cluster	Max. 8
Data packet size	24 Bytes
Energy consumptions in free space/air	0.01 n Joule/bit/m2

Table.1 *Parameters for Simulation*

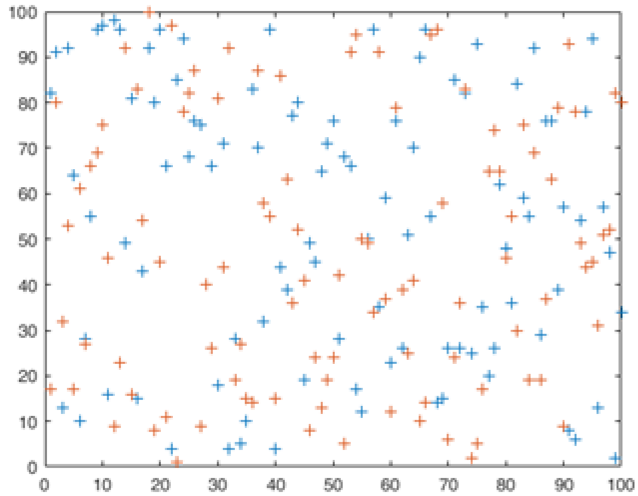

Fig. 5 *Deployment of Sensor Nodes in Non-uniform Fashion*

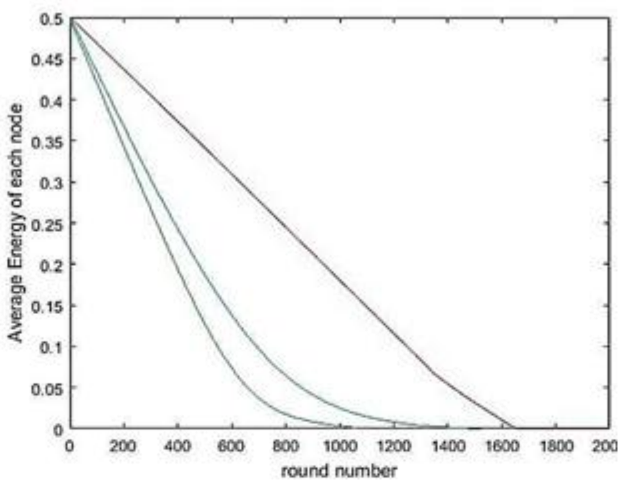

Fig.6 *Dead Node Ration Among LEACH, TEEN and HFTR*

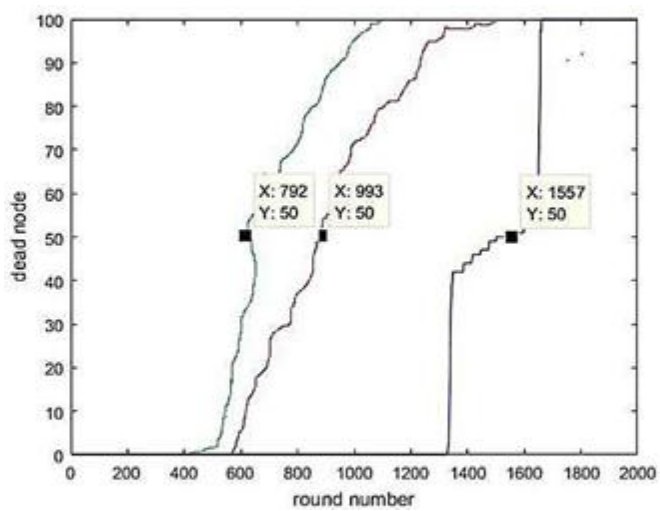

Fig.7 *Average Lifetime Comparison among LEACH, TEEN and HFTR*

Fig.5 illustrates the initial deployment of SNs in 100 × 100 area. Fig.6 and 7 show the outperformance of proposed HFTR algorithm against LEACH and TEEN. The performance of proposed HFTR compared in terms of the average lifetime of sensor network and dead node ration against the number of electoral rounds. In Fig.6 it is clearly reflected that the half-node dead position in case of LEACH, is 792 and for TEEN it is 993 whereas, for HFTR the half-node- deadposition is 1557. The performance of HFTR drastically improved because, by making BS mobile in nature, the load on individual SN level get reduced. Similarly, in Fig.7 it is clearly observed that the average lifetime of LEACH lies in between 1000 to 1100 electoral rounds and for TEEN it lies in between 1500 to 1600 whereas, for proposed HFTR in lies in between 1900 to 2000 electoral rounds. From, the entire performance graph, it can be concluded that the proposed HFTR performs better way than LEACH and TEEN.

5. CONCLUSION

Heterogeneous WSN is no way different from the internet of things (IoT) which invites several challenges to establish a compatible communication mode. Normally, in the heterogeneous mode, the variance in node nature is the biggest obstacle, which needs to be overcome by rigorous research. The core objective of any cluster-based routing protocol is to establish a secure connection among the nodes, extension of network lifetime. In this paper, we have proposed and energy efficient and fault tolerant clustering based routing protocol, which ensures the minimum energy dissipation by the SNs and enhancing the overall lifetime of the sensor network. The priority-based data transmission process reduces the traffic of CH to access the BS. In addition, the mobile BS reduces the distance between BS to CH which ultimately saves the energy of individual CH. The simulation results also prove the better performance of HFTR over well-known existing routing protocols such as LEACH and TEEN. This work may be extended by considering the total sensor network of mobile type because that creates another critical challenge of CH selection and positioning of BS.

REFERENCES:

[1] Invited Speech, Rafi Haladjian, “Internet of Things”, in Lift Asia 09, Korea, Sept 2009, http://www.youtube.com/watch?v=CeyWSlGLknY&NR=1.

[2] SENSEI: Integrating the physical with the digital world of the network, http://www.sensei-project.eu/.

[3] A. S. Toor and A. K. Jain, "A survey of routing protocols in Wireless Sensor Networks: Hierarchical routing," 2016 International Conference on Recent Advances and Innovations in Engineering (ICRAIE), Jaipur, 2016, pp. 1-6.

[4] Heinzelman W., Chandrakasan A., Balakrishnan H., “Energy-Efficient Communication Protocol for Wireless Microsensor Networks”, Proceedings of the 33rd Hawaii International Conf on System Sciences, January 2000.

[5] Manjeshwar and D. P. Agrawal, "TEEN: a routing protocol for enhanced efficiency in wireless sensor networks," Proceedings 15th International Parallel and Distributed Processing Symposium. IPDPS 2001, San Francisco, CA, USA, 2001, pp. 2009-2015.doi: 10.1109/IPDPS.2001.925197.

[6] Manjeshwar A., Agrawal D.P., “APTEEN: A Hybrid Protocol for Efficient Routing and Comprehensive Information Retrieval in Wireless Sensor Networks”, Proceedings of the International and Distributed Processing Symposium, 2002.

[7] Jeevan Kumar, SachinTripathi, and Rajesh Kumar Tiwari. 2016. A survey on routing protocols for wireless sensor networks using swarm intelligence. Int. J. Internet Technol. Secur. Syst. 6, 2 (January 2016), 79-102. DOI: http://dx.doi.org/10.1504/IJITST.2016.078574.

[8] Abbas Mohammed and Zhe Yang (December 14th 2010). A Survey on Routing Protocols for Wireless Sensor Networks, Sustainable Wireless Sensor Networks, Winston Seah and Yen Kheng Tan, IntechOpen, DOI: 10.5772/13942.

[9] A. Martirosyan, A. Boukerche and R. W. N. Pazzi, “A Taxonomy of Cluster-Based Routing Protocols for Wireless Sensor Networks,” Parallel Architectures, Algorithms, and Networks, I-SPAN 2008. International Symposium on, pp. 247-253, 2008.

[10] Mohamed, R.E., Saleh, A.I., Abdelrazzak, M. et al. Wireless PersCommun (2018) 101: 1019. https://doi.org/10.1007/s11277-018-5747-9.

[11] F. Bajaber and I. Awan, "Dynamic/Static Clustering Protocol for Wireless Sensor Network," Computer Modeling and Simulation, 2008. EMS '08. Second UKSIM European Symposium on, pp. 524-529, 2008.

[12] Xiong Qi Zheng, Yong Feng, Jie Yang and ZhiQiang Lu, "Energy efficient and Fault Tolerant Routing Protocol for Mobile Wireless Sensor Networks," 2014 International Conference on Information and Communications Technologies (ICT 2014), Nanjing, China, 2014, pp. 1-5.

[13] Mohapatra H., Rath A.K. (2019) Fault Tolerance Through Energy Balanced Cluster Formation (EBCF) in WSN. In: Tiwari S., Trivedi M., Mishra K., Misra A., Kumar K. (eds) Smart Innovations in Communication and Computational Sciences. Advances in Intelligent Systems and Computing, vol 851. Springer, Singapore.

[14] Shihan Li; DepeiQian; Yi Liu; Jie Tong, "Cluster-Based Multi-Path Data Dissemination Scheme for Large Scale Wireless Sensor Networks," Wireless Communications, Networking and Mobile Computing, 2007. WiCom 2007. International Conference on, pp.2715,2718, 21-25 Sept. 2007.

[15] Kemal Akkaya, Mohamed Younis, A survey on routing protocols for wireless sensor networks, Ad Hoc Networks, Volume 3, Issue 3, 2005, Pages 325-349, ISSN 1570-8705, https://doi.org/10.1016/j.adhoc.2003.09.010.

[16] Mohapatra, Hitesh; Rath, Amiya Kumar: 'Fault Tolerance in WSN Through PE-LEACH Protocol', IET Wireless Sensor Systems, 2019, DOI: 10.1049/iet-wss.2018.5229, IET Digital Library, https://digital-library.theiet.org/content/journals/10.1049/iet-wss.2018.5229.